# Prof. K. S. Shukla's contribution to the study of the history of Hindu astronomy *

I first visited Lucknow in November 1983 and studied the history of Indian astronomy under the guidance of Prof. Kripa Shankar Shukla until September 1987. Prof. Shukla's contribution to the study of the history of Hindu astronomy is so large and wide that it is beyond my ability to review his work in extenso, and the following are only some aspects of his work.

Those who want to know brief history and main characteristics of Hindu astronomy may first be referred to the following paper of Prof. Shukla.

(I) "Astronomy in Ancient and Medieval India", *Indian Journal of History of Science* (IJHS), Vol. 4, 1969, pp. 99–106.

## 1 Vedic and post-vedic astronomy

Prof. Shukla's view on the most ancient period of Hindu astronomy is seen in the following paper.

(II) "Main Characteristics and Achievements of Ancient Indian Astronomy in Historic Perspective", in G. Swarup, A. K. Bag and K. S. Shukla (eds.): *History of Oriental Astronomy*, Cambridge University Press, 1987, pp. 9–22.

This is a paper presented at the International Astronomical Union Colloquium held at New Delhi in November 1985. I also participated in this colloquium.

In the first part entitled "Vedic Astronomy" of the paper (II), Prof. Shukla summarises astronomical knowledge found in Vedic *Saṃhitās* and *Brāhmaṇas* and *Vedāṅga-jyotiṣa*. There are some controversial topics of ancient Hindu astronomy, and one topic, the origin of the name of the week days, may be mentioned here. Referring to P. V. Kane's work (1974),[1] Prof. Shukla says that the names of the week days are of Indian origin. The possibility of

* Yukio Ohashi, *Gaṇita-Bhāratī*, Vol. 17, Nos. 1–4 (1995), pp. 29–44. This paper was written as a dedication on the occasion of Platinum Jubilee Year of Dr. Shukla's birth (he was born on July 10, 1918).

[1] Kane, P. V.: *History of Dharmaśāstra*, Vol. V, part I, second ed., Bhandarkar Oriental Research Institute, Poona, 1974, pp. 677–685.


A. Kolachana et al. (eds.), *Studies in Indian Mathematics and Astronomy*,
Sources and Studies in the History of Mathematics and Physical Sciences,
https://doi.org/10.1007/978-981-13-7326-8_4

the Indian origin of the names of the week days was as P. V. Kane pointed out, already suggested by A. Cunningham (1885).[2] Usually, however, it is said that the names of the week days are of Hellenistic origin. If the seven planets are arranged according to their distance from the earth in Hellenistic geocentric model as "Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon", and distributed to each hour, which is of Egyptian origin as the lord of the hour, the planet of the first hour of a day determines the name of the day of the week. However, Cunningham suggested that if the seven planets are arranged in reverse order and distributed to each *ghaṭī* (one sixtieth of a day), which is of Indian origin, the planet of the first *ghaṭī* of a day determines the name of the day of the week. In my opinion, it is difficult to accept Cunningham's suggestion because later Hindu astronomical works mention lords of hours (*horā-īśas*)[3] and not lords of *ghaṭīs*.

In the second part entitled "Post-vedic Astronomy" of the paper (II), Prof. Shukla starts from the discussion of the *Vasiṣṭhasiddhānta* summarised in the *Pañcasiddhāntikā* of Varāhamihira, and proceeds to the *Pauliśasiddhānta* and the *Romakasiddhānta*, both summarised in the *Pañcasiddhāntikā* and Āryabhaṭa's works. In this period, motion of planets was studied besides the sun and moon. As Prof. Shukla has written some specialised papers on these topics, we shall discuss one by one.

## 2 The *Vasiṣṭhasiddhānta* summarised in the *Pañcasiddhāntikā*

The name of the sage Vasiṣṭha is mentioned in the *Yavana-jātaka* (chap. 79, vs. 3) (AD 269/270) of Sphujidhvaja, and it may be that the *Vasiṣṭhasiddhānta* existed at the time of Sphujidhvaja. The *Vasiṣṭhasiddhānta* was summarised in the *Pañcasiddhāntikā* (the 6th century AD) of Varāhamihira. Among five *siddhāntas* summarised in the *Pañcasiddhāntikā*, the *Paitāmahasiddhānta*, which is the earliest and was written in AD 80, is based on the five-year *yuga* system just like the *Vedāṅga-jyotiṣa*. The *Vasiṣṭhasiddhānta* is the next oldest *siddhānta* to the *Paitāmahasiddhānta*. Varāhamihira only states that the theory of the shadow at the latter part of chapter II of his *Pañcasiddhāntikā* is based on the *Vāsiṣṭha-samāsa-siddhānta*, and it is not clear whether the luni-solar theory at the former part of chapter II and the planetary theory at the former part of chapter XVII are based on the *Vasiṣṭhasiddhānta* or not.[4] In his pa-

[2] Cunningham, A.: "The Probable Indian Origin of the Names of the Week-days", *The Indian Antiquary*, Vol. XIV, 1885, pp. 1–4. This view was criticised by J. Burgess (*The Indian Antiquary*, Vol. XIV, 1885, pp. 322–323.

[3] See, for example, *Āryabhaṭīya* (III. 16), *Sūryasiddhānta* (XII. 79) etc.

[4] In chapter XVII (chap. XVIII of Thibaut and Dvivedin's ed.) of the *Pañcasiddhāntikā*, a colophon after a verse (XVII. 5) reads, "*vāsiṣṭha-siddhānte śukraḥ*", but Varāhamihira

per (II), Prof. Shukla considers that the luni-solar theory and the planetary theory are based on the *Vasiṣṭhasiddhānta*, just like Kuppanna Shastri as well as Neugebauer and Pingree considered so.

Prof. Shukla explained Vasiṣṭha's theory for the moon's motion in the second part of the following paper.[5]

(III) "The *Pañcasiddhāntikā* of Varāhamihira (2)", *Gaṇita*, Vol. 28, 1977, pp. 99–116.

As regards the *Vasiṣṭhasiddhānta*, one topic may be mentioned here. The name of Viṣṇucandra is mentioned in the *Brāhmasphuṭasiddhānta* (XI. 50) (AD 628) of Brahmagupta as the editor of the *Vasiṣṭhasiddhānta*. S. B. Dīkshit (1896) wrote that Viṣṇucandra's version of the *Vasiṣṭhasiddhānta* did not exist at the time of Varahamihira, because he considered that the name Viṣṇucandra is not mentioned in the *Pañcasiddhāntikā*[6]. On the contrary, Prof. Shukla considers that the name of Viṣṇucandra appears in the *Pañcasiddhāntikā*. He discusses Viṣṇucandra and Romaka criticised by Pauliśa in the first part of the following paper.

(IV) "The *Pañcasiddhāntikā* of Varāhamihira (1)", *Gaṇita*, Vol. 24, No. 1, 1973, pp. 59–73: reprinted in *IJHS*, Vol. 9, 1974, pp. 62–76.

In this paper, Prof. Shukla identifies "Vishnu" in the *Pañcasiddhāntikā* (III. 32) with Viṣṇucandra, the editor of the *Vasiṣṭhasiddhānta*. Prof. Shukla remarks that occurrence of criticism of Viṣṇucandra, Romaka etc. in the *Pañcasiddhāntikā* shows that Brahmagupta's critical remarks against them were not totally baseless. This point will have to be investigated further.

## 3 The *Yuga* of the *Yavana-jātaka*

The *Yavana-jātaka* (AD 269/270) of Sphujidhvaja, edited and translated by David Pingree,[7] is an important text to investigate Greek influence of astronomy and astrology into India. The last chapter (chap. 79) of this work deals

himself does not state the source.

[5] For Vasiṣṭha's theory for the moon's motion, the following papers may also be consulted:
Kharegat, M. P. : "On the Interpretation of certain passages in the Pancha Siddhāntikā of Varāhamihira, an old Hindu Astronomical Work", *The Journal of the Bombay Branch of the Royal Asiatic Society*, Vol. XIX, 1895–97, pp. 109–141; and
Kuppanna Sastri, T. S.: "The Vāsiṣṭha Sun and Moon in Varāhamihira's Pañcasiddhāntikā", *Journal of Oriental Research*, Madras, Vol. XXV, 1955–56, pp. 19–41.

[6] Dikshit, Sankar Balakrishna, tr. by R. V. Vaidya: *Bharatiya Jyotish Sastra*, part II, Calcutta, 1981. David Pingree also thinks that Viṣṇucandra is later than Varāhamihira, because Viṣṇucandra used *mahāyuga* and epicycles, which are absent in Varāhamihira's version of the *Vasiṣṭhasiddhānta* (Neugebauer, O. and D. Pingree: *The Pañcasiddhāntikā of Varāhamihira*, part I, Copenhagen 1970, p. 10.)

[7] Pingree, David: The *Yavana-jātaka of Sphujidhvaja*, 2 vols., Harvard University, Cambridge, Mass., 1978.

with mathematical astronomy on the basis of 165-year *yuga*. In the following paper, Prof. Shukla corrects some errors of Pingree, and explains the *yuga* of the *Yavana-jātaka* in lucid manner.

(V) "The *Yuga* of the *Yavana-jātaka*, David Pingree's text and translation reviewed", *IJHS*, Vol. 24, 1989, pp. 211–223.

Among several points pointed out by Prof. Shukla, I would like to mention the number of *tithis* and civil days in a *yuga* (165 years). Pingree interpreted that the *Yavana-jātaka* (chap. 79, vss. 6–7) states that there are 60265 civil days in a *yuga*, and that there are 61230 *tithis* in a *yuga*. Prof. Shukla has shown that these verses actually state that there are 61230 *tithis* and 60272 civil days in a *yuga*. Prof. Shukla has given mainly textual evidences to prove his interpretation, which are quite sound and understandable. We can also notice that the verses (chap. 79, vss. 8–9) state that the risings of the moon in a *yuga* are 58231, and the number of conjunctions of the sun and moon is 2041. The sum of 58231 and 2041, that is 60272, should be the number of civil days in a *yuga*. This fact shows that Prof. Shukla's reading is correct.

## 4 The *Pauliśa* and the *Romakasiddhānta* summarised in the *Pañcasiddhāntikā*

Among five *siddhāntas* summarised in the *Pañcasiddhāntikā*, the *Pauliśa* and the *Romakasiddhānta* are considered to be more accurate than the *Paitāmaha* and the *Vasiṣṭhasiddhānta*. Main characteristics of the *Pauliśa*- and the *Romakasiddhānta* are described in the paper (II) of Prof. Shukla. Some particular topics are discussed in his papers (III) and (IV).

In the fourth part of his paper (IV), Prof. Shukla discusses a correction of the Pauliśa school to the longitude of the moon's ascending node. He further points out that the followers of the *Pauliśasiddhānta* fell in with the followers of the *Āryabhaṭasiddhānta* (midnight system), and revised the *Pauliśasiddhānta*, and also adopted the *Pūrva-Khaṇḍakhādyaka* of Brahmagupta as a work of their school. In the first part of his paper (IV), Prof. Shukla discusses Pauliśa's criticism of Viṣṇucandra and Romaka. In the first part of his paper (III), Prof. Shukla discusses the epoch of the *Romakasiddhānta*.

## 5 The *Āryabhaṭīya* of Āryabhaṭa I

The *Āryabhaṭīya* (AD 499) of Āryabhaṭa (b. AD 476) is the earliest Sanskrit astronomical work whose author and date are definitely known. Prof. Shukla published a critical edition of the *Āryabhaṭīya* with English translation and notes.

(VI) *Āryabhaṭīya of Āryabhaṭa*, critically edited with translation and notes, in collaboration with K. V. Sarma, *Indian National Science Academy* (*INSA*), New Delhi, 1976.

Prof. Shukla also published the text of the *Āryabhaṭīya* with the commentary of Bhāskara I (AD 629) (extant up to IV. 6) and Someśvara (sometime between 968 and 1200 AD) (being a summary of Bhāskara I's commentary, and published after IV. 6).[8]

(VII) *Āryabhaṭīya of Āryabhaṭa*, with the commentary of Bhāskara I and Someśvara, *INSA*, New Delhi, 1976.

Before Prof. Shukla's translation of the *Āryabhaṭīya*, there existed two published complete English translations of the *Āryabhaṭīya*, one by P. C. Sengupta (1927),[9] and the other by W. E. Clark (1930).[10] At their time, only available printed text of the *Āryabhaṭīya* was H. Kern's edition (1874) with the commentary of Parameśvara (the 15th century AD). After that, Nīlakaṇṭha Somayajin's commentary (the early 16th century AD) was also published in the Trivandrum Sanskrit Series (1930–1957).

The significance of Prof. Shukla's work is that he consulted several commentaries, both published and unpublished, and made critical edition in collaboration with K. V. Sarma and translated into English with detailed notes. Especially, Bhāskara I's commentary, which was published by Prof. Shukla for the first time, is important, because it is the earliest extant commentary on the *Āryabhaṭīya*, and Bhāskara I was a follower of Āryabhaṭa school and must have been accessible to several informations handed down to Āryabhaṭa's successors. Sarma edited another commentary.[11]

## 6 Āryabhaṭa I's midnight system

There were controversies about Āryabhaṭa since the beginning of the study of Indian astronomy and mathematics. H. T. Colebrooke[12] considered that the

[8] Bhāu Dājī (1865) once announced to publish the *Āryabhaṭīya* with the commentary of Someśvara (Bhāu Dājī: "Brief Notes on the Age and Authenticity of the Works of Āryabhaṭa, Varāhamihira, Brahmagupta, Bhaṭṭotpala, and Bhāskarācārya", *Journal of The Royal Asiatic Society*, 1865, 392–418; p. 405.) It could not see the light of day.

[9] Sengupta, P. C.: "The *Āryabhaṭīyam*", *Journal of the Department of Letters, University of Calcutta*, Vol. 16, 1927, art. 6, pp. 1–56.

[10] Clark, Walter Eugene: *The Āryabhaṭīya of Āryabhaṭa*, University of Chicago, 1930. In the preface, he writes that this work was partly based on the work done with him by Baidyanath Sastri for the degree of M.A.

[11] K. V. Sarma (ed.): *Āryabhaṭīya* of Āryabhaṭa with the commentary of Sūryadeva Yajvā, INSA, New Delhi, 1976.

[12] Colebrooke, H. T.: *Algebra with Arithmetic and Mensuration, from the Sanscrit of Brahmegupta and Bhāscara*, London, 1817, notes G and I.

*Daśagītikā* and the *Āryāṣṭaśata* (both of which form what we call *Āryabhaṭīya* of Āryabhaṭa I) are Āryabhaṭa's genuine work, while J. Bentley[13] considered that the *Āryasiddhānta* (which we call *Mahāsiddhānta* of Āryabhaṭa II) is Āryabhaṭa's genuine work. Fitz-Edward Hall (1860)[14] thought that both are genuine, and suspected that there were two Āryabhaṭas. Commenting to Hall's paper, W. D. Whitney[15] wrote that these two Āryabhaṭas were considered to be one person by Brahmagupta, who criticised Āryabhaṭa's inconsistency. Whitney's view is actually wrong, and Āryabhaṭa II is a later person whose date is controversial.[16] Bhāu Dājī (1865)[17] clearly pointed out that there were two Āryabhaṭas, but made a mistake that the only work of Āryabhaṭa known to Brahmagupta etc. was the *Āryabhaṭīya*. He was not aware of Āryabhaṭa I's work of midnight system.[18] After that, S. B. Dikshit[19] and Sudhākara Dvivedin[20] rightly suggested that Āryabhaṭa I might have written two works, that is the *Āryabhaṭīya* and another work of midnight system. P. C. Sengupta (1930)[21] wrote a paper on Āryabhaṭa's lost work of midnight system, and investigated its astronomical constants etc.

Āryabhaṭa's work of midnight system is not extant, but there remain some information in the works of later authors, such as the *Khaṇḍakhādyaka* of Brahmagupta. The *Mahābhāskarīya* of Bhāskara I gave further informations about Āryabhaṭa I's midnight system.[22]

Prof. Shukla made further progress of the study of Āryabhaṭa's midnight system. In the following paper, Prof. Shukla described several aspects of Āryabhaṭa I's midnight system, and published a fragment of the *Yantrādhyāya* (chapter on astronomical instruments) of the *Āryabhaṭasiddhānta* (Āryabhaṭa I's lost work of midnight system), found in Rāmakṛṣṇa Ārādhya's commentary (AD 1472) on the *Sūryasiddhānta*.

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[13]Bentley, John: *A Historical View of the Hindu Astronomy*, Calcutta, 1823, part II, section III.

[14]Hall, Fitz-Edward: "On the Āryasiddhānta", *Journal of the American Oriental Society*, Vol. 6, 1866, pp. 556–559.

[15]Committee of Publication (= W. D. Whitney): "Additional Note on Āryabhaṭṭa and his Writings", *Journal of the American Society*, Vol. 6, 1866, pp. 560–564.

[16]J. Bentley and Bhāu Dājī thought it is the 14th century AD, S. B. Dikshit thought the 10th century, D. Pingree thinks between ca. 950 and 1100, and R. Billard thinks the 16th century.

[17]Bhāu Dājī, *op. cit.*

[18]The *Āryabhaṭīya* is based on sunrise system (*audayika*), where a civil day is reckoned from sunrise. In the midnight system (*ārdharātrika*), a civil day is reckoned from midnight.

[19]Dikshit, tr. by Vaidya, *op. cit.*, part II, pp. 58–59.

[20]Dvivedin, Sudhākara (ed.): *Brāhma-sphuṭa-siddhānta*, ed. with the commentary written by Dvivedin, Benares, 1902; commentary on (XI. 13).

[21]Sengupta, P. C.: "Āryabhaṭa's Lost Work", *Bulletin of the Calcutta Mathematical Society*, Vol. 22, 1930, pp. 115–120.

[22]Sengupta, P. C. (tr. into English): *Khaṇḍakhādyaka*, Calcutta, 1934. Introduction, pp. x–xx.

(VIII) "Āryabhaṭa I's astronomy with midnight day-reckoning", *Gaṇita*, Vol. 18, No. 1, 1967, pp. 83–105.

This fragment, published for the first time, is a very important source material of the development of astronomical instruments in India. Prof. Shukla's edition of the fragment is based on a manuscript (deposited in Lucknow University, Acc. no. 45749) of Rāmakṛṣṇa Ārādhya's commentary on the *Sūryasiddhānta*, which is a transcription from a manuscript (no. 2803) of the Government Oriental Library, Mysore.

In the following paper, Prof. Shukla described some informations about the *Āryabhaṭasiddhānta* mentioned in Mallikārjuna Sūri's commentary (AD 1178) on the *Sūryasiddhānta* and Tamma Yajvā's commentary (AD 1599) on the *Sūryasiddhānta*.

(IX) "Glimpses from the *Āryabhaṭasiddhānta*", *IJHS*, Vol. 12, 1977, pp. 181–186.

It is very important to study these early commentaries on the *Sūryasiddhānta*, none of which has been published.

As regards the chronological order of the two works of Āryabhaṭa I, Prof. Shukla says in his paper (VIII) that they were written in the following order: (i) *Āryabhaṭasiddhānta*, and (ii) *Āryabhaṭīya*.

## 7 The *Sūryasiddhānta* summarised in the *Pañcasiddhāntikā*

According to Varāhamihira, the *Sūryasiddhānta* is the most accurate among the five *siddhāntas* summarised in his *Pañcasiddhāntikā*. This old *Sūryasiddhānta* is different from the modern *Sūryasiddhānta* which is extant now. Differences between these two *Sūryasiddhāntas* are discussed by Prof. Shukla in the Introduction of the following book.

(X) *The Sūryasiddhānta with the commentary of Parameśvara*, (Hindu Astronomical and Mathematical Text Series No. 1), Lucknow, 1957.

In this book (p. 27), Prof. Shukla wrote that the works of Āryabhaṭa I and Lāṭadeva were based on the *Sūryasiddhānta*, and rejected P. C. Sengupta's view that the old *Sūryasiddhānta* was made up-to-date by Varāhamihira by replacing the old constants in it by new ones from Āryabhaṭa I's midnight system. In his papers (VIII) and (IV) also, Prof. Shukla wrote that Āryabhaṭa I's midnight astronomy was based on the old *Sūryasiddhānta*. It seems that Prof. Shukla modified his view later, and wrote in the Introduction of his book (VI) (p. lxiii) that the *Āryabhaṭasiddhānta* is based on the earlier *Sūryasiddhānta*, which is now lost, and that the *Sūryasiddhānta* summarised in

the *Pañcasiddhāntikā* is a new version revised by Lāṭadeva in the light of the *Āryabhaṭasiddhānta*. In his paper (II) also, Prof. Shukla wrote that the *Sūryasiddhānta* summarised by Varāhamihira was simply a redaction of the larger work of Āryabhaṭa.

Prof. Shukla corrected some errors in Thibaut and Dvivedin's edition of the *Pañcasiddhāntikā* in the following paper.

(XI) "On three stanzas from the *Pañcasiddhāntikā*", *Gaṇita*, Vol. 5, No. 2, 1954, pp. 129–136.

In this paper, Prof. Shukla presented the corrected reading of the *Pañcasiddhāntikā* (XVII. 12)[23] and (IX. 15–16),[24] and made clear that the astronomical constants in the old *Sūryasiddhānta* recorded in them are harmonious with those ascribed to Āryabhaṭa I's midnight system recorded by Bhāskara I.

In the third part of his paper (IV), Prof. Shukla discussed a correction for Mercury and Venus in the old *Sūryasiddhānta*. It may be noted that Prof. Shukla utilised the *Sumati-Mahātantra* of Sumati of Nepal.

## 8 The *Pañcasiddhāntikā* of Varāhamihira

As we have seen in connection of each *siddhānta* summarised in the *Pañcasiddhāntikā*, Prof. Shukla has written three papers on the *Pañcasiddhāntikā*, viz. papers (XI), (IV), and (III).

In the third part of his paper (III), Prof. Shukla discussed the 30 days of the Parsi calendar mentioned in the *Pañcasiddhāntikā* (I. 23–25). He compared them with the corresponding names given by Vaṭeśvara (AD 904), and verified them. It may be noted that the result is different from readings of Thibaut and Dvivedin, M. P. Kharegat, and Neugebauer and Pingree.

In the second part of his paper (IV), Prof. Shukla discussed the declination table of Varāhamihira.

## 9 Bhāskara I

Bhāskara I (the 7th century AD), who is a contemporary of Brahmagupta, is a different person from Bhāskara II (the 12th century AD) who wrote the *Siddhānta-śiromaṇi* etc. H. T. Colebrooke was aware of the existence of Bhāskara I cited by Pṛthūdaka Svāmin, but he could not find any work written by him.[25] B. Datta secured the works of Bhāskara I, and wrote a

[23] This is (XVI. 23) in Neugebauer and Pingree's edition.
[24] M. P. Khareghat also proposed similar correction. (See Khareghat, *op. cit.*, pp. 132–134.)
[25] Colebrooke, *op. cit.*, note H.

paper on him (1930).[26] However, Datta misunderstood that Bhāskara I is a direct disciple of Āryabhaṭa I, and that he lived in the first half of the 6th century AD. T. S. Kuppanna Sastri pointed out that Bhāskara I is not a direct disciple of Āryabhaṭa I, but he could not ascertain Bhāskara I's date exactly.[27] Prof. Shukla has shown that Bhāskara I actually lived in the 7th century AD, because Bhāskara I wrote his commentary on the *Āryabhaṭīya* in 629 AD, and accordingly not a direct disciple of Āryabhaṭa I. (See his book (VII), Introduction, pp. xix-xxv). Prof. Shukla also pointed out that Bhāskara I belonged to Aśmaka country lying between the rivers Godāvari and Narmadā, but lived in Valabhī in Saurāṣṭra (in modern Gujarat). (*Ibid.*, pp. xxv-xxx.)

Bhāskara I wrote three works. One is a commentary on the *Āryabhaṭīya*. Other two are the *Mahābhāskarīya* and the *Laghubhāskarīya*, and Prof. Shukla published them with English translation.

(XII) *Mahābhāskarīya*, Lucknow, 1960.

(XIII) *Laghubhāskarīya*, Lucknow, 1963.

There are other editions of the *Mahābhāskarīya*[28] and *Laghūbhāskarīya*,[29] but there is no other English translation.

Prof. Shukla discussed spherical astronomy of Bhāskara I and his contemporary Brahmagupta in the following paper.

(XIV) "Early Hindu Methods in Spherical Astronomy", *Gaṇita*, Vol. 19, No. 2, 1968, pp. 49–72.

He also discussed mathematics of Bhāskara I in the following papers.

(XV) "Hindu Mathematics in the seventh century as found in Bhāskara I's commentary on the *Āryabhaṭīya*", (1) *Gaṇita*, Vol. 22, No. 1, 1971, pp. 115–130; (2) *Gaṇita*, Vol. 22, No. 2, 1971, pp. 61–78; (3) *Gaṇita*, Vol. 23, No. 1, 1972, pp. 57–79; (4) *Gaṇita*, Vol. 23, No. 2, 1972, pp. 41–50.

## 10 Āryabhaṭa School

The *Āryabhaṭīya* of Āryabhaṭa I laid the foundation of the Āryabhaṭa school, of which one of the most eminent astronomer is Bhāskara I, whom we have

[26] Datta, Bibhutibhusan: "The Two Bhāskaras", *The Indian Historical Quarterly*, Vol. VI, 1930, pp. 727–736.

[27] Kuppanna Sastri, T. S.: "*Mahābhāskarīya of Bhāskarācārya*", Madras Government Oriental Series No. cxxx. Madras, 1957, Introduction, pp. xiii–xvii.

[28] Ānandāśrama edition (with Parameśvara's commentary), Pune, 1945; and Kuppanna Sastri's edition (with Govindasvāmin's commentary and Parameśvara's super-commentary). *op. cit.*

[29] Ānandāśrama edition (with Parameśvara's commentary), Pune, 1946; and Trivandrum edition (with Śankaranārāyaṇa's commentary), Trivandrum, 1949.

just discussed. The Āryabhaṭa school flourished in South India, particularly in Kerala, rather than in North India.

T. S. Kuppanna Shastri wrote a paper (1969)[30] on the peculiarities of Āryabhaṭa school, but he misunderstood the computation of the equation of centre in this school. Prof. Shukla criticised Kuppanna Shastri's paper, and explained the computation of the equation of centre of Āryabhaṭa school in the following paper.

(XVI) "Use of Hypotenuse in the Computation of the Equation of the Centre under the Epicyclic Theory in the School of Āryabhaṭa I ???", *IJHS*, Vol. 8, 1973, pp. 43–57.

In this paper, he quotes from the works of astronomers of Āryabhaṭa school, viz. Bhāskara I (AD 629), Govinda Svāmī (c. 800–850), Parameśvara (1430), Nīlakaṇṭha (c. 1500), and Putumana Somayājī (1732).

Prof. Shukla also published the *Karaṇaratna* (AD 689) of Deva, belonging to Āryabhaṭa school, for the first time.

(XVII) *The Karaṇaratna of Devācārya*, Lucknow, 1979.

Deva belonged to South India, probably Kerala. Prof. Shukla points out that the *Karaṇaratna* is the earliest preserved work where three *bīja* corrections, viz. the *Śakābda* correction, the *Kalpa* correction, and the *Manuyuga* correction, are stated, and also it is probably the first work in the Āryabhaṭa school to have given a rule for finding the value of the precession. So, this is a very important work of Hindu astronomy.

## 11 The *Śiṣyadhīvṛddhidatantra* of Lalla

The *Śiṣyadhīvṛddhidatantra* of Lalla (the 8th or 9th century AD)[31] is also a text following Āryabhaṭa. Bina Chatterjee edited its text with the commentary of Mallikārjuna Sūri (the 12th century AD), and translated into English, but chapter XXI (chapter of astronomical instruments) was left untranslated by Chatterjee who passed away in 1978. So, its translation was supplied by Prof. Shukla, and published as follows:

Bina Chatterjee: *Śiṣyadhīvṛddhida Tantra of Lalla*, 2 parts, *INSA*, New Delhi, 1981.

[30] Kuppanna Shastri, T. S.: "The School of Āryabhaṭa and the Peculiarities thereof", *IJHS*, Vol. 4, pp. 126–134.

[31] Bina Chatterjee wrote that the date of Lalla is sometime between the 8th and the 11th century, (Introduction of her edition and translation, part II, p. xiv.) Prof. Shukla says that Lalla's date is sometime between AD 665 (*Khaṇḍakhādyaka's* date) and AD 904 (*Vaṭeśvarasiddhānta's* date): see Introduction of his book (VI), p. lx.

Lalla described several instruments, some of which are quite different from those of early authors, and his description is very important.

## 12 The *Vaṭeśvarasiddhānta* of Vaṭeśvara

The *Vaṭeśvarasiddhānta* (AD 904) of Vaṭeśvara (b. AD 880) is the largest Sanskrit astronomical work. It is well known that Brahmagupta criticised Āryabhaṭa I. Vaṭeśvara reversely criticised Brahmagupta, and defended Āryabhaṭa I.

The first three chapters of the *Vaṭeśvarasiddhānta* were first published by Ram Swarup Sharma and Mukund Misra in 1962,[32] but it was based on a single manuscript. Prof. Shukla discovered another manuscript of the *Vaṭeśvarasiddhānta*, and reported its contents etc. in the following paper.

(XVIII) "Hindu astronomer Vaṭeśvara and his works", *Gaṇita*, Vol. 23, No. 2, 1972, pp. 65–74.

It may be noted that Prof. Shukla identified Vaṭeśvara's place Ānandapura with Vadnagar in northern Gujarat.

Prof. Shukla edited the whole text of the *Vaṭeśvarasiddhānta* based on these two manuscripts, and the fragment of the *Gola* found in the newly discovered manuscript, and translated them into English with detailed commentary.

(XIX) *Vaṭeśvarasiddhānta and Gola of Vaṭeśvara*, 2 parts, *INSA*, New Delhi, 1985–1986.

Prof. Shukla's commentary is so detailed and lucid that it is particularly useful for those who want to understand the theory of Hindu astronomy deeply. Explaining several topics, Prof. Shukla refers to parallel passages in other Sanskrit astronomical works extensively, and this book can be used as a standard reference book of Hindu astronomy. The list of word-numerals, which is appendix II of part I, is perhaps the most exhaustive list of word-numerals.

David Pingree of Brown University, U.S.A, has written a review of this book (XIX). (*IJHS*, Vol. 26, 1991, pp. 115–122.)

It is known that al-Bīrūnī has quoted from the *Karaṇasāra*, a calendrical work of Vateśvara. The *New Catalogus Catalogorum* (Vol. 3, p. 176) of Madras University records a manuscript of the "*Karaṇasāra of Vitteśvara*" in the "State Library", Kota, Rajasthan, but its actual existence has not been ascertained so far. I was suggested this fact by Prof. Shukla, and visited Kota once, but could not find the *Karaṇasāra* during my short stay.

It may be noted that the original idea of the second correction for the moon, which is stated in the *Laghumānasa* of Mañjula as we shall see below,

[32] *Vaṭeśvarasiddhānta*, Vol. I, Indian Institute of Astronomical and Sanskrit Research, New Delhi, 1962.

is attributed to Vaṭeśvara by Yallaya (1482 AD), but it is not found in the extant *Vaṭeśvarasiddhānta*. Prof. Shukla suggests that it must have been mentioned in the *Karaṇasāra* or some other work of Vaṭeśvara. (See p. LIII, Introduction of part II of his book (XIX).)

## 13 The *Laghumānasa* of Mañjula

The name of Mañjula is sometimes spelt Muñjāla, but, according to Prof. Shukla, Mañjula is the real name.

H. T. Colebrooke (1816)[33] already noticed the notion of the precession of Mañjula quoted in the *Siddhāntaśiromaṇi* (*Gola*, VI. 17–18) of Bhāskara II. According to Bhāskara II, Mañjula stated that the equinox revolves 199669 times in a *kalpa*, that is $59''.9007$ per year. Colebrooke has not seen Mañjula's own work, but we know that Mañjula himself gives the rate of precession as $1'$ per year in his *Laghumānasa*. Reason of this discrepancy is not known.

The *Laghumānasa* (AD 932) of Mañjula was noticed by Sudhākara Dvivedin (1892),[34] and N. K. Majumder (1927)[35] etc. Dvivedin pointed out that the second correction for the moon is mentioned there. The second correction, which is a combination of the deficit of the equation of centre and the evection, was further discussed by D. Mukhopadhyaya (1930)[36] and P. C. Sengupta (1932).[37] Later, N. K. Majumder published an edition and English translation (1940–1951)[38] of the *Laghumānasa*, and Ānandāśrama of Pune published (1944)[39] the text with Parameśvara's commentary.

Prof. Shukla pointed out in the following paper that the interpretations of D. Mukhopadhyaya and P. C. Sengupta contain some errors, and discussed the second correction of Mañjula etc. in detail.

(XX) "The Evection and the Deficit of the Equation of the Centre of the Moon in Hindu Astronomy", *Proceedings of the Benares Mathematical Society*, New Series, Vol. 7, No. 2, 1945, pp. 9–28.

[33] Colebrooke, H. T.: "On the Notion of the Hindu Astronomers concerning the Precession of the Equinoxes and Motion of the Planets", *Asiatic Researches*, Vol. XII, 1816, pp. 209–250; reprinted in his *Miscellaneous Essays*, Vol. II, 1837.

[34] Dvivedin, Sudhākara, *Gaṇaka-taraṅgiṇī*, 1892, section of Muñjāla.

[35] Majumder, N. K.: "*Laghumānasam* of Muñjāla", *Journal of the Department of Letters, University of Calcutta*, Vol. 14, 1927, art. 8, pp. 1–5.

[36] Mukhopadhyaya, Direndranath: "The Evection and the Variation of the Moon in Hindu Astronomy", *Bulletin of the Calcutta Mathematical Society*, Vol. XXII, 1930, pp. 121–132.

[37] Sengupta, P. C.: "Hindu Luni-solar Astronomy", *Bulletin of the Calcutta Mathematical Society*, Vol. 24, 1932, pp. 1–18; reprinted as appendix I of his English translation of the *Khaṇḍakhādyaka*, Calcutta, 1934.

[38] Majumder, N. K.: *Laghumānasam by Muñjalācārya*, Calcutta, 1951. He states in its Introduction that he took up the work in 1940, and published the first instalment in a journal.

[39] *Laghumānasam*, Ānandāśrama Sanskrit Series 123, Pune, 2nd ed., 1952.

According to this paper, Mañjula's second correction for the moon's longitude in terms of minutes can be expressed as follows:

$$\pm\left(8\frac{2}{15}\right)\cos(S-U)[G-11]\times\left(8\frac{2}{15}\right)\sin(M-S)$$

where S, M, U, respectively denote the true longitudes of the sun, the moon, and the moon's apogee, and $G$ the Moon's true daily motion in degrees. Formerly, D. Mukhopadhyaya took S, M, G as the mean longitudes of the sun and the moon, and the mean daily motion of the moon respectively, and P. C. Sengupta and N. K. Majumder (1951) took $G$ as the mean daily motion of the moon, although they took $M$ as the moon's longitude corrected by the first equation. Prof. Shukla says that $G$ should be the *true* daily motion of the moon, because Vaṭeśvara (quoted in Yallaya's commentary on the *Laghumānasa*) states the corresponding term to be the true motion. (As we have discussed, Vaṭeśvara's statement is not found in the extant *Vaṭeśvara-siddhānta*.)

Besides Mañjula, Prof. Shukla explained in his paper (XX) the second correction for the moon in the *Siddhāntaśekhara* (1039 AD) of Śrīpati, the *Tantra-Saṃgraha* of Nīlakaṇṭha (ca. 1500 AD), and the *Siddhāntadarpaṇa* of Candra Śekhara Siṃha (later half of the 19th century). And also, using a figure, Prof. Shukla explained the rationale of this second correction, which is explained in Hindu astronomy as the displacement of the Earth from its natural position.

Recently, Prof. Shukla published a new critical edition and English translation of the *Laghumānasa* of Mañjula with detailed introduction and notes.

(XXI) "*A Critical Study of the Laghumānasa of Mañjula*", *IJHS*, Vol. 25, 1990, Supplement; and also separately issued, *INSA*, New Delhi, 1990.

The *Laghumānasa* is a small but very important work. Prof. Shukla's notes with rationale and examples are quite useful to understand the text.

## 14 The *Dhīkoṭida-karaṇa* of Śrīpati and the *Rājamṛgāṅka* of Bhoja

Śrīpati wrote three astronomical works, the *Siddhāntaśekhara*, the *Dhīkoṭida-karaṇa* (AD 1039), and the *Dhruvamānasa-karaṇa* (AD 1056).

He also wrote the mathematical work *Gaṇitatilaka*, and several astrological works such as the *Ratnamāla*, the *Jātakapaddhati* etc. The *Siddhāntaśekhara* was published by B. Miśra (1932, 1947),[40] and the *Dhīkoṭida-karaṇa* was

[40] *The Siddhāntaśekhara of Śrīpati*, 2 parts, ed. by Babuāji Miśra, Calcutta University, 1932–1947.

(according to D. Pingree) published by N. K. Majumder (1934),[41] but the *Dhruvamānasa-karaṇa* has not been published.

Prof. Shukla published a critical edition and English translation of the *Dhīkoṭida-karaṇa* with notes and illustrative examples.

(XXII) "*The Dhīkoṭida-karaṇa of Śrīpati*", Akhila Bhāratīya Sanskrit Parishad, Lucknow, 1969.

This is a small work which gives the method of calculation of lunar and solar eclipses. Prof. Shukla has given illustrative examples of the calculation using Śrīpati's method for the eclipses in 1968 AD, and showed that the result is remarkably good.

By the way, it may also be noted that the second correction for the moon in the *Śiddhānta-śekhara* has been discussed in Prof. Shukla's paper (XX).

Another contemporary *karaṇa* work is the *Rājamṛgāṅka* (1042 AD) of Bhoja. Prof. Shukla has written the following comment on the printed text of the *Rājamṛgāṅka*.

(XXIII) "A Note on the Rājamṛgāṅka of Bhoja published by the Adyar Library", *Gaṇita*, Vol. 5, No. 2, 1954, pp. 149–151.

In this paper, Prof. Shukla has shown that K. M. K. Sarma's edition of the *Rājamṛgāṅka* published by the Adyar Library, Madras (1940), may not be the original and full text, but an abridged edition by some later writer.

## 15 The early versions of the modern *Sūryasiddhānta*

The modern *Sūryasiddhānta* (called "Modern" in contrast with the *Sūryasiddhānta* summarised in the *Pañcasiddhāntikā* of Varāhamihira) is one of the most popular Sanskrit work of astronomy. There are several extant traditional commentaries since the 12th century down to recent time, and also, there are several researches by modern scholars since the end of the 18th century, the earliest of whom is perhaps Samuel Davis (1790).[42] Another early scholar is John Bentley (1799),[43] who analysed the accuracy of the *Sūryasiddhānta*, and

[41] Majumder, N. K.: "Dhīkoṭi-karaṇa of Śrīpati", *Calcutta Oriental Journal*, Vol. I, 1934, pp. 286–299. The calculation in the *Dhīkoṭi-karaṇa* was already explained in Majumder: "Dhīkoṭi-karaṇam of Śrīpati", *Journal of the Asiatic Society of Bengal*, N.S., Vol. XVII, 1921, pp. 273–278. I have not seen his paper of 1934, but have seen his paper of 1921. Differences between his reading and Prof. Shukla's reading exist in the apparent diameters of the sun, the moon, and the shadow of the earth. Perhaps Majumder took the reading "*rasāgni*" (= 36) (in verse 8–d) for the moon's diameter in terms of minutes, while Prof. Shukla takes "*karāgni*" (= 32).

[42] Davis, Samuel: "On the Astronomical Computations of the Hindus", *Asiatic Researches*, Vol. 2, 1790, pp. 175–226.

[43] Bentley, J.: "On the Antiquity of the Sūrya Siddhānta and the Formation of the Astronomical Cycles therein contained", *Asiatic Researches*, Vol. 6, 1799, pp. 540–593.

concluded that it was composed in the eleventh century or so. As regards the date of the modern *Sūryasiddhānta*, Prof. Shukla writes in the Introduction (p. 29) of his book (X) that it is sometime between AD 628 and AD 966, after AD 628 because it is influenced by *Brāhmasphuṭasiddhānta*, and before AD 966 because Bhaṭṭotpala wrote a commentary on it, whose fragment is quoted in a later work.

In the 19th century, the text of the *Sūryasiddhānta* with Raṅganātha's commentary (AD 1603) was published by Fitz Edward Hall and Bāpūdeva Śāstrī (1854–58),[44] and Bāpūdeva Śāstrī translated it into English (1860–62).[45] Ebenezer Burgess also published an English translation of the *Sūryasiddhānta* with the help of W. D. Whitney (1860),[46] and this has become one of the most popular work of Hindu astronomy in English. Burgess' translation is also based on Raṅganātha's commentary. There are some other printed editions of the Sanskrit text of the *Sūryasiddhānta* based on Raṅganātha's version.

There are several earlier extant commentaries of the *Sūryasiddhānta*, such as

(i) Mallikārjuna Sūri (AD 1178)

(ii) Caṇḍeśvara (AD 1185)

(iii) Madanapāla (the 14th century AD)

(iv) Parameśvara (AD 1432)

(v) Yallaya (AD 1472)

(vi) Rāmakṛṣṇa Ārādhya (AD 1472)

(vii) Bhūdhara (AD 1572)

(viii) Tamma Yajvan (AD 1599)

The readings of the text in these early versions are different from Raṅganātha's version at several places. Prof. Shukla published the *Sūryasiddhānta* with Parameśvara's commentary for the first time (1957) as his book (X). In the footnotes of this book, Prof. Shukla gives alternative readings of the text found in the versions of Mallikārjuna Sūri, Yallaya, Rāmakṛṣṇa Ārādhya, and Raṅganātha also. At present this book is only one printed text of an early

[44] Published in the Bibliotheca Indica series of the Asiatic Society, Calcutta.

[45] Bāpūdeva Śāstrī and Lancelot Wilkinson: *The Sūrya siddhānta, or an Ancient System of Hindu Astronomy followed by the Siddhānta Śiromaṇi*, Asiatic Society, Calcutta, 1860–1862.

[46] Burgess, Ebenezer: "Translation of the Sūryasiddhānta", *Journal of the American Oriental Society*, Vol. 6, 1860, pp. 141–498. Reprinted by Calcutta University in 1935.

version of the *Sūryasiddhānta* before Raṅganātha. So, this is an indispensable work to investigate the early form of the modern *Sūryasiddhānta*.

We also recall that Prof. Shukla published a fragment of the *Āryabhaṭasiddhānta* of Āryabhaṭa I quoted in Rāmakṛṣṇa Ārādhya's commentary on the *Sūryasiddhānta* in his paper (VIII), and also discussed about the informations about the *Āryabhaṭasiddhānta* found in Mallikārjuna Sūri and Tamma Yajvā's commentaries on the *Sūryasiddhānta* in his paper (IX).

Early commentaries on the *Sūryasiddhānta* are mine of informations of Hindu astronomy, and much more study is necessary.

## 16 Other works

Papers (I) and (II) may be said to be general papers. Prof. Shukla has written the following paper also.

(XXIV) "Phases of the Moon, Rising and Setting of Planets and Stars and their Conjunctions", in S. N. Sen and K. S. Shukla (eds.): *History of Astronomy in India*, *INSA*, New Delhi, 1985.

This paper is complementary to Arka Somayaji's "The Yuga System and the Computation of Mean and True Longitudes" and S. D. Sharma's "Eclipses, Parallax and Precession of Equinoxes" in the same book.

Prof. Shukla also made several contributions to the study of Hindu Mathematics. He published the *Pāṭīgaṇita* of Śrīdhara (Lucknow, 1959), and the *Bījagaṇitāvataṃsa* of Nārāyaṇa. (Akhila Bharatiya Sanskrit Parishad, Lucknow, 1970), and also revised B. Datta and A. N. Singh's papers on Hindu Geometry, Trigonometry, Calculus, Magic squares, Permutations and combinations, Series, Surds, and Approximate values of surds, and published in *IJHS* (vols. 15, 18, 19, 27, and 28).

## 17 Conclusion

We have seen that Prof. Shukla's works cover almost all periods of Classical Hindu Astronomy, and are based on several primary sources. Several fundamental Sanskrit texts were critically edited and translated with detailed mathematical and astronomical notes which are lucid and exact. I believe that all students of the history of Indian astronomy should study the works of Prof. Shukla carefully.